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Focus issue introduction: nanoplasmonics and metamaterials

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Abstract: This focus issue of *Optical Materials Express* reflects new trends in nanoplasmonics and metamaterials presented by leading groups in the field.

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References and links

1. J. Pendry, "Introduction," Opt. Express **11**(7), 639 (2003).

Light-matter interaction at the nanometer scale has turned into a very fast growing field of research known as Nano-Optics. The first main motivation behind such enthusiasm comes from the potential of Nano-Optics to extend concepts and functionalities of conventional optics down to the nanometer scale, moving toward ultracompact photonic devices that are not limited by diffraction. Beyond miniaturization, an additional motivation arises from the rich new physics involved when matter is downsized to dimensions that are much smaller than the light wavelength.

Research in nanoplasmonics and metamaterials are very well representative of the tremendous increase of activities in Nano-Optics, and are both expected to have a strong impact on our society.

Nanoplasmonics studies the optical properties of nanoscale systems supporting surface plasmons and has gained a great deal of attention after the discovery of surface-enhanced Raman scattering (SERS) in the 1970s. Benefiting from recent advances in nanofabrication techniques, research in nanoplasmonics has recently been very successful in using noble metal (especially silver and gold) nanostructures to control light fields well *beyond the limit of diffraction*. Such control has already contributed to enhancing light interaction with tiny amounts of matter down to the *single-molecular level*.

In the field of metamaterials, researchers aim at designing ensembles of subwavelength units that behave as effective materials featuring properties that are not found in nature. Originally born from early research in the 1950s on microwave engineering for antenna beam shaping, artificial materials have recently regained a huge interest triggered by provocative theoretical proposals such as *super lensing* and *invisibility* at optical frequencies as well as the successful experimental demonstration of *negative refraction*. The effective properties of metamaterials often employ plasmonic nanostructures, providing a tight connection between the two fields. Since one of the first focus issues on negative refraction and metamaterials was published in *Optics Express* in 2003 [1], the field has grown from 80 to 1200 publications per year, according to the Web of Science.

At this very exiting stage of research in nanoplasmonics and metamaterials, further advances are in part conditioned by the development of new optical materials with improved properties as well as advances in nanofabrication techniques to increase the quality of constitutive nano-units. The past few years have seen a growing tendency toward advancing the material research in order to address some major roadblocks faced by both fields. Thus it

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is an ideal time to compile a special issue of *Optical Materials Express* that reflects some of the latest advances along these directions.

In the fields of plasmonics and plasmonic metamaterials, reduction in metal losses is of obvious importance and crucial for potential applications. In their paper, Naik and co-authors explore the use of alternative materials such as conducting oxides and transition-metal nitrides that feature lower intrinsic absorption than conventional plasmonic metals. Atomic layer deposition of Al-doped ZnO for the three-dimensional design of metamaterials is demonstrated by Frölich and Wegener. Kehr *et al.* develop subdiffraction imaging devices for the terahertz spectral range based on phonon resonances of perovskite-type oxides. Alternatively, Campione *et al.* study another approach in which the metal losses are compensated by the introduction of a gain material.

The article by Tamayo-Rivera and colleagues investigates a hybrid material formed by silver nanoparticles and Si quantum dots that feature enhanced third-order nonlinearity.

The ability to define nano-units with a very high accuracy and reproduce them with ease and low cost over large areas will become a key ingredient toward the elaboration of future optical devices based on plasmonics and metamaterials. Along this direction, Barnakov *et al.* discuss a novel approach based on silver-filled alumina templates as a way to achieve curved metamaterials. Also based on self-assembly, the strategy proposed by Christke and co-authors enables achieving aligned gold nanoantennas into a high refractive index dielectric matrix. Finally, Burckel *et al.* report a novel variant of projection lithography capable of creating three-dimensional metallic inclusions. The method can produce complicated arrangements of loops including gaps to build structures supporting both electric and magnetic resonances.

Von Cube *et al.* also show in this special issue the importance of advanced characterization tools, such as electron energy-loss spectroscopy (EELS) combined with transmission electron microscopy, capable of probing with a subwavelength resolution the properties of individual nano-units in metamaterials. Clarkson *et al.* study fundamentals of plasmonic building blocks with three-dimensional finite-difference time-domain simulations. In their paper the authors discuss the scaling behavior of the dipole and quadrupole modes in plasmonic nanoparticle pairs. Photoluminescence from light-emitting polymer films mediated by surface plasmon polaritons at the metal–film interface is investigated by Stavrinou with co-authors as of great practical importance for active plasmonic devices.

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